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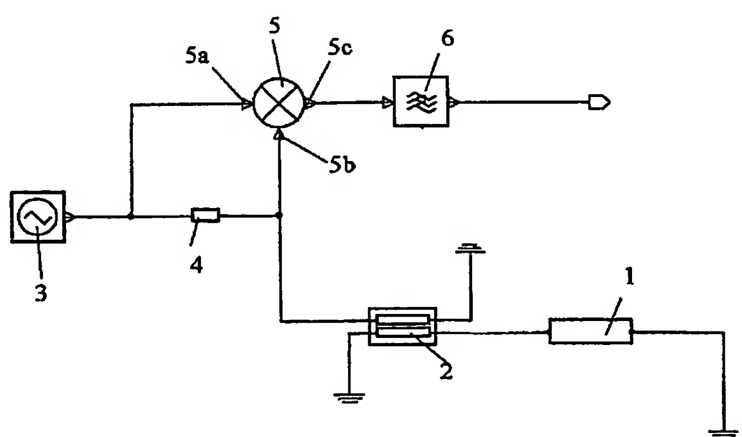
(54) Title: IMPROVED METHOD AND APPARATUS FOR TRACKING A RESONANT FREQUENCY



(57) Abstract: An arrangement for tracking the resonant frequency of one or more electrically resonant structures (11, 21) through a single channel comprises a variable frequency oscillator (13, 23) associated with the or each resonant structure (11, 21) which provides an excitation signal of a variable frequency encompassing the possible resonant frequency of the associated resonant structure. Coupling means (2) are provided which connect the or each variable frequency oscillator (13, 23) to said resonant structure(s). An I-mixer (15, 25) is provided for each oscillator (13, 23) which forms a synchronous detector, a first input (15a, 25a) of each I-mixer (15, 25) being connected to its associated oscillator (13, 23) and a second input (15b, 25b) being connected to the coupling device (2), the or each I-mixer (15, 25) mixing the excitation signal from the associated variable frequency oscillator (13, 23) with a response signal generated by the resonant structure(s) in response to the or each excitation signal. The output of the or each I-mixer (15, 25) is filtered to remove the sum products of the excitation and response signals, thereby leaving just an amplitude modulation component of the signal, which is then processed in a control loop to track the resonant frequency of the or each resonant structure.

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Improved Method and Apparatus for tracking a resonant frequency

The present invention relates to improved methods for tracking resonant frequencies of electrically resonant structures, in particular structures which are mounted remotely from the driving and sensing electronics.

International patent application no. WO 98/21818 discloses a system for tracking the resonant frequency of an electrically resonant structure in which a variable frequency oscillator, which generates an excitation signal of a variable frequency encompassing the possible resonant frequency range of the target resonant structure, is connected to the resonant structure by a bi-directional RF transmission line. The proportion of the excitation signal energy reflected and the proportion dissipated by the resonant structure will depend upon the difference between the frequency of the excitation signal and the resonant frequency of the resonant structure, and the transmission line incorporates a directional coupler, which generates a directional coupler signal proportional to the reflected signal from the resonant structure. The directional coupler signal is conditioned by a processor to provide a feedback signal to the input of the variable frequency oscillator, such that the mean frequency of the excitation signal is caused continuously to track the varying resonant frequency of the resonant structure.

This arrangement has particular application in the of non-contact torque measurement using SAW (surface acoustic wave) devices as the sensing elements. Many such applications, however, use two SAW devices attached to a rotating shaft in such a way that when torque is applied one resonator is put in tension whilst the second is put in compression. This causes the resonant frequency of the first device to reduce whilst the second will increase. The two devices would normally have a nominal difference between them of 1 MHz, such that with torque the output from the system is a difference frequency that changes about 1 MHz with applied torque. However, in order to be used in conjunction with the tracking system of the prior art, the two

sensors on the shaft must be electrically connected to the stator of the assembly via two pairs of non-contacting rotary coupled transmission lines. The use of two pairs of couplers has the disadvantage that the size and complexity of the mechanical assembly is increased, and thereby the cost. In addition, the rotary coupled transmission line can load the SAW resonator and thereby modify its frequency. As the system is a differential one, if both couples modify their respective sensor response by the same amount, then this effect can be cancelled out, but if the two channels are not identical then an error in the reading obtained can result.

The arrangement of the prior art has the further disadvantage that the requirement for a directional coupler increases the complexity of the arrangement.

According to one aspect of the present invention there is provided a method of tracking the resonant frequency of an electrically resonant structure comprising the steps of exciting the resonant structure with a reference signal of a variable frequency encompassing the possible resonant frequency of the resonant structure, mixing a response signal from the resonant structure with the reference signal, filtering the mixed response and reference signals to remove the sum products from the composite signal, and using the resulting amplitude modulation component of the response signal within a control loop to track the resonant frequency of the resonant structure.

The present invention further provides an apparatus for tracking the resonant frequency of an electrically resonant structure, comprising a variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency of said resonant structure, coupling means connecting said variable frequency oscillator to said resonant structure, an I-mixer forming a synchronous detector having a first input connected to said oscillator and a second input connected to the coupling device, the I-mixer mixing the excitation signal from the variable frequency oscillator with a response signal generated by the resonant structure in response to the excitation signal, a filter connected to the output of the I-

mixer which filters the output of the I-mixer to remove the sum products of excitation and response signals, thereby leaving just an amplitude modulation component of the signal, and processing means which processes the filtered signal to track the resonant frequency of the resonant structure.

An apparatus for and method of tracking a resonant frequency in accordance with the invention has the advantage that it enables multiple resonant structures to be connected together and interrogated through a single channel, whilst, at the same time, obviating the need for a directional coupler to be used.

Preferably, the reference signal from the oscillator is mixed, through the coupling means, with a second reference signal from a second oscillator of a variable frequency encompassing the possible resonant frequency of a second resonant structure, the first and second resonant structures having a nominal difference frequency, and said first and second resonant structures are excited with said mixed signal. The composite response signal of said first and second resonant structures is then mixed with the first reference signal, the mixed signal filtered using a filter, preferably a low pass filter, and the resulting signal used within a control loop to track the resonant frequency of the first resonant structure, and it is also mixed with the second reference signal, by a separate mixer, the mixed signal filtered and the resulting signal used within a control loop to track the resonant frequency of the second resonant structure. In this way, it is possible to track the resonant frequency of a pair of structures connected in parallel through a single channel. The coupling of the two signals to the resonant structures is preferably achieved by use of a summer connected to the input of the coupling means.

An impedance such as a resistor is preferably provided between the oscillator and the resonant structure, in particular between the oscillator and the coupling means. Furthermore, the or each signal source preferably has a low output impedance, which has the advantage of suppressing any amplitude modulation of the or each reference signal.

In a particularly preferred embodiment of the invention, a Q-mixer is provided for the or each signal source, to one input of which is connected the signal source through a phase shifter which shifts the reference signal received at the first input by preferably 90 degrees, and to the other input of which is connected the coupling means so as to deliver the response signal thereto. The output of the or each Q-mixer is similarly filtered to remove the sum products of the input signals, thereby leaving just the amplitude modulation component of the response signal. The square of that signal is then summed with the square of the filtered signal output of the associated I-mixer and then processed to track the resonant frequency of the associated resonant structure. In this way, errors in the tracked frequency resulting from the phase delay of the signal at the input of the coupling device are eliminated.

The squaring and summing operations may be carried out digitally by use of A/D converters and suitable digital processing means, which may also calculate first harmonic amplitudes of the demodulated signals produce codes for controlling the carrier frequency of the signal sources. Alternatively, analogue signal squaring means may be utilised, such as a mixer with its inputs linked.

It will, of course, be understood that the system may be expanded to tracked the resonant frequencies of more than two structures, such as SAW devices. For such multiple resonant structures, there is preferably a nominal frequency difference between each device of at least 1 MHz.

In order that the invention may be well understood, there will now be described some embodiments thereof, given by way of example, reference being made to the accompanying drawings, in which:

Figure 1 is a simplified schematic representation of a system embodying the invention suitable for tracking the resonant frequency of a single structure;

Figure 2 is a schematic representation of a system embodying the invention suitable for tracking the resonant frequency of two resonant structures; and

Figure 3 is a schematic representation of a system according to an alternative embodiment containing two resonant structures with I and Q synchronous detectors.

Referring first to Figure 1, there is shown a simplified schematic of a system embodying the invention. The output of a signal source 3 is connected directly to one input 5a of a mixer 5 and through a resistor 4 to the input of a coupling device 2, which, in turn, is connected to a single SAW resonator 1. The input of the coupling device 2 is also connected to a second input 5b of the mixer 5. The coupling device preferably takes the form of a rotational contactless coupler, but other coupling devices are also possible, and the signal source 3 takes the form of a high frequency oscillator with a centre frequency within the bandwidth of the resonator 1 and it is frequency modulated again within a deviation that is within the bandwidth of the resonator.

Upon operation of the system, the SAW resonator 1 is excited by the reference signal from the signal source 3. The impedance of the SAW resonator 1 will change rapidly with frequency around its resonant point and will form a potential divider with the resistor 4, so that when the impedance of the resonator 1 is high compared with that of the resistor 4, there will be minimal voltage drop across the resistor 4, whereas when the impedance of the resonator 1 is low compared with that of the resistor 4, there will be a large voltage drop across the resistor 4 and minimal across the resonator 1. In this way, the amplitude of the response of the SAW 1 to the reference signal, as seen at the second input 5b of the mixer 5 from the coupling device 2, will also vary as the frequency of the signal source 3 is modulated. By using a signal source 3 of low output impedance, the amplitude modulation of the output of the signal source 3 fed to the first input 5a of the mixer will be suppressed. As a result, the mixer 5, acting as a

synchronous detector, will output through its output line 5c a signal which will be the sum of the driving signal from the signal source 3 and the amplitude modulated signal response of the resonator 1. A low pass filter 6 is then used to remove the sum products of the signals, leaving just the amplitude modulation component of the signal which can then be used within a control loop to track the resonant frequency of the SAW device 1 in the manner described in WO98/21818.

In a development of this embodiment not illustrated, a buffer is inserted in front of the resistor 4 that further reduces the parasitic amplitude modulation in the reference signal.

Figure 2 shows a schematic representation of how the system of Figure 1 can be used to connected together and interrogate two SAW resonators which have a nominal difference frequency of, say, 1Mhz through a single channel which requires just a single coupling device. The two SAW devices 11, 21 are arranged in parallel and connected to the coupling device 2 which is, in turn, connect to the output of a summer 20. One input of the summer 20 is connected to one input 15b of a first mixer 15 and through a first resistor 14 to a first signal source 13 which generates a first reference signal, the first signal source also being coupled directly to the other input 15a of the first mixer 15. The other input of the summer 20 is connected to one input 25b of a second mixer 25 and through a second resistor 24 to a second signal source 23 which generates a second reference signal, the second signal source also being coupled directly to the other input 25a of the second mixer 25. Each of the signal sources 13, 23 takes the form of a high frequency oscillator with a centre frequency within the bandwidth of its associated resonator 11, 21 and it is frequency modulated again within a deviation that is within the bandwidth of its associated resonator 11, 21. The coupling device 2 again preferably takes the form of a rotational contactless coupler, but other coupling devices are also possible.

Each half of the system then operates in the same manner as described above in relation to Figure 1, with the reference signal from the first signal source 13 exciting the first SAW 11 and the reference signal from the second signal source 23 exciting the second SAW 21. The amplitude modulated response signals from the two SAWs 11, 21 will then be fed back through the coupling device 2 and the combined signals fed to the inputs 15b, 25b of both the first and the second mixer 15, 25 by the summer 20. At the first mixer 15, the combined response signal is mixed with the reference signal from the first signal source 13 and the sum products are then removed by the first low pass filter 16 connected to the output 15c of the first mixer 15. Furthermore, because of the nominal difference frequency between the two SAWs and because the amplitude modulation caused by each SAW device 11, 21 will be at the same fundamental and harmonic frequencies, the output of the first low pass filter 16 can easily be processed electronically in a manner well known to the skilled person to separate out the amplitude modulated component of the response from the first SAW 11. This can then be used within a control loop to the first signal source 13 to track the resonant frequency of the first SAW 11.

Similarly, at the second mixer 25, the combined response signal is mixed with the reference signal from the second signal source 23 and the sum products are then removed by a second low pass filter 26 connected to the output 25c of the second mixer 25. The output of the second low pass filter 26 can then be processed electronically to separate out the amplitude modulated component of the response from the second SAW 21 due to the nominal frequency difference between the first and second SAWS 11, 21. This can then be used within a control loop to the second signal source 23 to track the resonant frequency of the second SAW 21.

For example, if the SAW devices 11, 21 have nominal frequencies of 200MHz and 201 MHz, giving a nominal difference frequency of 1 MHz and the amplitude modulation caused by each SAW device is at 5kHz with the 2nd harmonics at 10kHz, these will be excited by the reference signals produced by the two signal sources 13,

23 having frequencies of 200MHz FM and 201 MHz FM respectively. When the 200Mhz FM signal is mixed with the composite 200 and 201 MHz FM response signal with amplitude modulation from the SAWs 11, 21, the difference product will be the 5kHz signal generated by the modulation due to the excitation of the 200MHz SAW, the modulation caused by the 201 MHz device being offset by 1MHz and therefore easily filtered out. Similarly, when the 201 MHz FM signal is mixed with the composite response signal, the modulation caused by the 200 MHz SAW can also easily be filtered out.

A drawback with the embodiments described above in relation to Figures 1 and 2 is that the actual frequencies that will be tracked using the demodulated signal produced by the synchronous detector will slightly differ from the resonant frequency of the SAW device and the amount of this difference will depend on the phase delay of the signal at the input of the coupling device. In some cases it may be difficult to ensure a high stability of the phase delay, which will result in random errors in the measurement of the resonant frequency. Figure 3 shows a third embodiment of the invention in which phase delay effects are eliminated by mixing the reference and response signals for each signal source in an IQ mixer and producing the demodulated signal as a sum of the squares of the signals at I (in-phase) and Q (Quadrature) outputs of the IQ mixers 30, 40. This is achieved by supplementing the system of figure 2 with an additional pair of Q-mixers 32, 42, one associated with each signal source 13, 23.

One input of the first Q-mixer 32 associated with the first signal source 13 is connected to the first signal source 13 through a 90 degree phase shifter 31 so as to receive a phase shifted version of the reference signal from the first signal source 13. The other input of the first Q-mixer 32 is connected to the summer 20 so as to receive the response signals from the two SAW devices 11, 21. The output of the first Q-mixer 32 is then filtered using a low pass filter 33 before being squared and then summed with the filtered and squared output of the first mixer 15, which is based in

the in-phase reference signal. The sum of the squares of these two signals will not, then, depend on the phase delay of the input signal.

The squaring and summing of the signals may be achieved by analogue means using looped mixers 34, 35 and a summer as shown in Figure 3. Alternatively, the output of the low pass filters 16, 33 can be converted into digital signals using A/D converters and the squaring and adding of the signals performed by a digital processor. Apart from performing the squaring and adding functions, the digital processor will also calculate the first harmonic amplitudes of the demodulated signals and produce the codes that will control the carrier frequencies of the digital synthesisers used as the signal sources.

It will, of course, be understood that a second Q-mixer 42, phase shifter 41 and low pass filter 43 will be associated with the second signal source 23.

Claims

1. A method of tracking the resonant frequency of an electrically resonant structure comprising the steps of exciting the resonant structure with a reference signal of a variable frequency encompassing the possible resonant frequency of the resonant structure, mixing a response signal from the resonant structure with the reference signal, filtering the mixed response and reference signals to remove the sum products from the composite signal, and using the resulting amplitude modulation component of the response signal within a control loop to track the resonant frequency of the resonant structure.

2. A method according to claim 1, comprising the further step of summing the reference signal from said oscillator with a second reference signal of a variable frequency encompassing the possible resonant frequency of a second resonant structure, the first and second resonant structures having a nominal difference frequency, exciting said first and second resonant structures with said mixed signal, mixing the composite response signal of said first and second resonant structures with the first reference signal, filtering the mixed signal and using the resulting signal within a control loop to track the resonant frequency of the first resonant structure, and mixing the composite response signal of said first and second structures with said second reference signal, filtering the mixed signal and using the resulting signal within a control loop to track the resonant frequency of the second resonant structure.

3. A method according to claim 1 or claim 2, wherein the or each mixed response and reference signals are filtered using a low pass filter.

4. A method according to any of the preceding claims, comprising the further step of suppressing the amplitude modulation of the or each reference signal by using a signal source of low output impedance.

5. A method according to any of the preceding claims, wherein the or each reference signal passes through an impedance before exciting the or each resonant structure.

6. A method according to any of the preceding claims, comprising the further step, for the or each reference signal, of mixing the response signal with a phase shifted version of the or each reference signal, filtering said mixed signal, squaring the filtered in-phase and phase shifted mixed response and reference signals, summing the associated squared signals and using the result within a control loop to provide a phase compensated track of the resonant frequency of the associated resonant structure.

7. A method according to claim 6, wherein the reference signal is phase shifted through 90 degrees.

8. An apparatus for tracking the resonant frequency of an electrically resonant structure, comprising a variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency of said resonant structure, coupling means connecting said variable frequency oscillator to said resonant structure, an I-mixer forming a synchronous detector having a first input connected to said oscillator and a second input connected to the coupling device, the I-mixer mixing the excitation signal from the variable frequency oscillator with a response signal generated by the resonant structure in response to the excitation signal, a filter connected to the output of the I-mixer which filters the output of the I-mixer to remove the sum products of excitation and response signals, thereby leaving just an amplitude modulation component of the signal, and processing means which processes the filtered signal to track the resonant frequency of the resonant structure.

9. An apparatus according to claim 8 for tracking the resonant frequencies of a pair of electrically resonant structures having a nominal difference frequency, further

comprising a second variable frequency oscillator connected to the coupling means, said first variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency of the first resonant structure and said second variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency of the second resonant structure, a second I-mixer forming a synchronous detector associated with the second oscillator having its first input connected to the second oscillator and its second input connected to the coupling device so as to mix the excitation signal from the second oscillator with a composite response signal received from said first and second resonant structures, and a second filter connected to the output of the second I-mixer which filters the output signal.

10. An apparatus according to claim 9, wherein said first and second resonant structure are connected in parallel.

11. An apparatus according to claim 9 or claim 10, further including a summer having first and second inputs connected to the first and second oscillators respectively, and an output connected to the coupling means.

12. An apparatus according to any of claims 8 to 11, wherein the or each filter is a low pass filter.

13. An apparatus according to any of claims 8 to 12, further comprising an impedance connected between the or each oscillator and the coupling device, the first input of the or each I-mixer being connected between its associated oscillator and its impedance and the second input of the or each I-mixer being connected between the associated impedance and the coupling device.

14. An apparatus according to any of claims 8 to 13, further including a Q-mixer associated with the or each oscillator having a first input connected to its associated

oscillator by means of phase shifting means and a second input connected to the coupling means such that the or each Q-mixer mixes a phase shifted version of the excitation signal from its associated oscillator with the response signal, a filter connected to the output of the or each Q-mixer which removes the sum products of the phase shifted excitation and response signals, so as to leave just an amplitude modulation component of the signal, and further including means associated with the or each oscillator for squaring and then summing the filtered signals from the I- and Q-mixers associated with the or each oscillator, said processing means processing the sum of the squares of the filtered signals from said I- and Q- mixers, whereby phase delay effects are eliminated.

15. An apparatus according to claim 14, wherein the or each phase shifting means phase shifts the signal by 90 degrees.

16. An apparatus according to claim 14 or claim 15, wherein said means for squaring and summing said signals comprises first analogue signal squaring means connected to the filtered output of the or each I-mixer, a second analogue squaring means connected to the filtered output of the or each Q-mixer, and a summer associated with the or each pair of I and Q mixer having a first and second inputs connected to the outputs of the associated first and second squaring means.

17. An apparatus according to claim 16, wherein the said analogue signal squaring means each comprise a mixer having first and second inputs connected together to the output of its associated filter.

18. An apparatus according to claim 14 or claim 15, wherein said means for squaring and summing the signals comprises a digital processor, the output of each filter being connected to an analogue to digital converter which is, in turn, connected to an input of the digital processor.

19. An apparatus according to claim 18, wherein the or each digital processor also calculates first harmonic amplitudes of the demodulated signals and produces codes for controlling the carrier frequency of the signal source.

20. An apparatus according to any of claims 8 to 19, wherein the coupling means is a rotational contactless coupler.

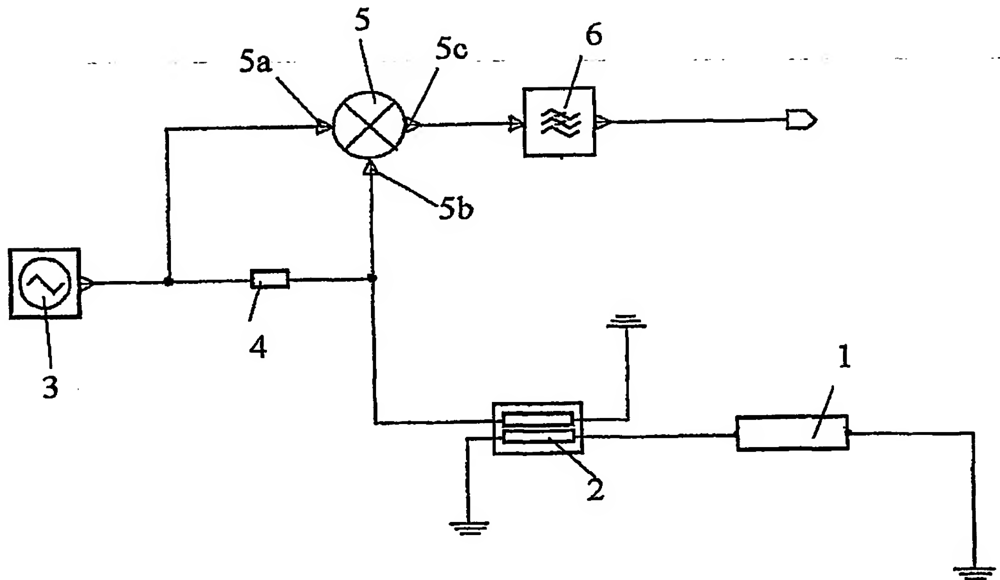

Figure 1

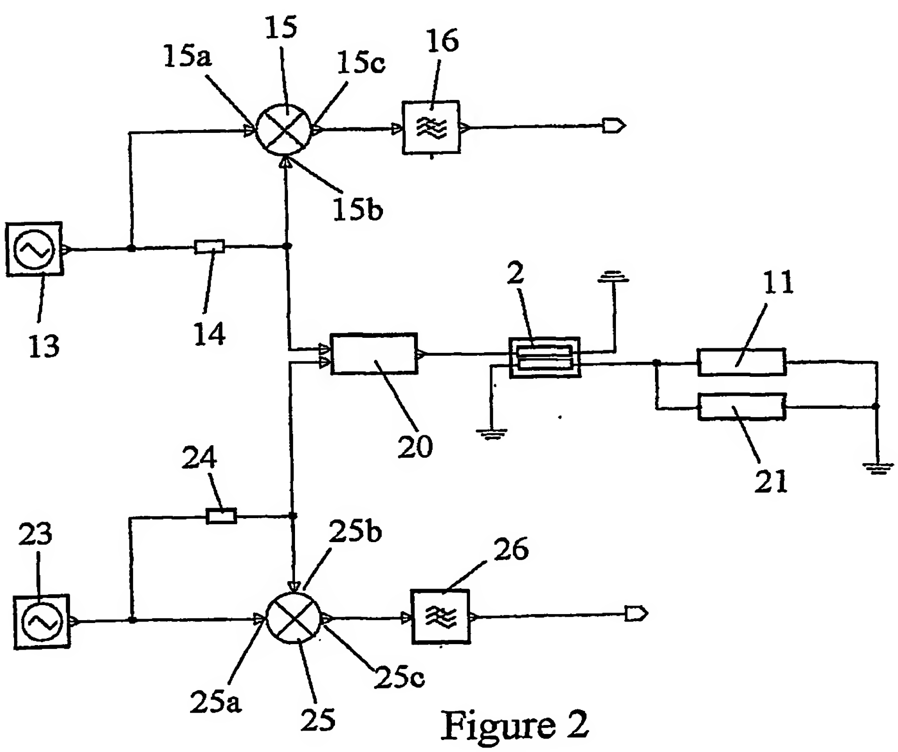

Figure 2

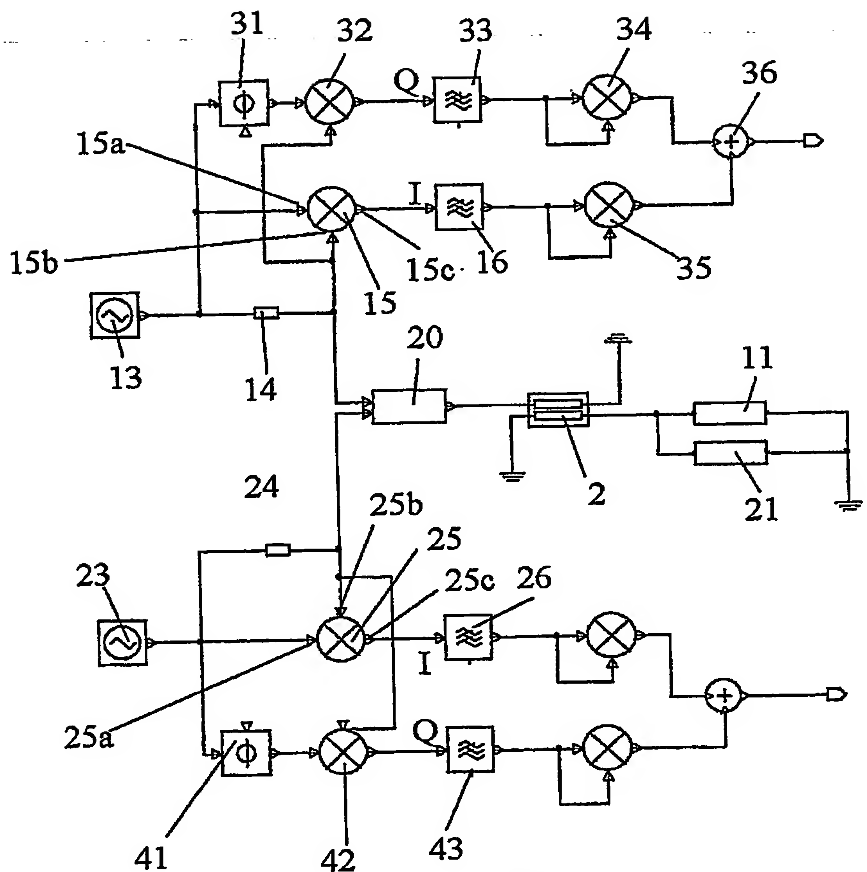
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Figure 3

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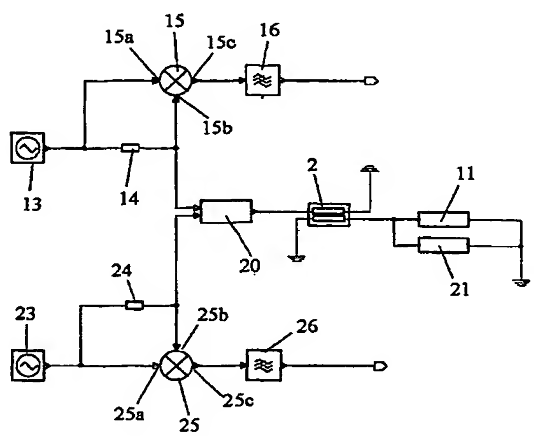

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Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/46684 A (LEE SHING M ; LEHMAN KURT R (US); FIELDEN JOHN (US); JOHNSON WALT (US)) 28 June 2001 (2001-06-28) figure 2 page 13, lines 10,11,18,19 page 14, lines 7,8,19 page 15, lines 11-13 page 16, lines 13,14 -----	1,8
A	GB 2 355 801 A (TRANSENSE TECHNOLOGIES PLC) 2 May 2001 (2001-05-02) abstract; figures 1,2 page 7, line 9 -----	1-20
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 September 2004	20/09/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Plathner, B-D

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INTERNATIONAL SEARCH REPORT

national Application No
T/GB 03/01627

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WOLFF, U.; DICKERT, F.L.; FISCHERAUER, G.K.; GREIBL, W.; RUPPEL, C.C.W.: "SAW sensors for harsh environments" SENSORS JOURNAL, IEEE, vol. 1, no. 1, July 2001 (2001-07), pages 4-13, XP002294979 page 6, left-hand column, line 37 - right-hand column, line 24 figure 2	1-20
A	US 5 585 571 A (LONSDALE ANTHONY ET AL) 17 December 1996 (1996-12-17) abstract figure 9	1-20

1

Form PCT/ISA/210 (continuation of second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

Information on patent family members

national Application No
..T/GB 03/01627

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 0146684	A	28-06-2001	US	6707540	B1	16-03-2004
			US	6433541	B1	13-08-2002
			EP	1244907	A1	02-10-2002
			JP	2003522937	T	29-07-2003
			WO	0146684	A1	28-06-2001
			US	6621264	B1	16-09-2003
GB 2355801	A	02-05-2001	NONE			
US 5585571	A	17-12-1996	AT	156262	T	15-08-1997
			AU	655764	B2	12-01-1995
			AU	7334191	A	10-10-1991
			BR	9106101	A	24-02-1993
			CA	2077085	A1	04-09-1991
			DE	69127074	D1	04-09-1997
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			WO	9113832	A2	19-09-1991
			JP	3108881	B2	13-11-2000
			JP	5506504	T	22-09-1993
			KR	199230	B1	15-06-1999

PATENT COOPERATION TREATY

REC'D 27 OCT 2004
WIPO PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Article 36 and Rule 70)

Applicant's or agent's file reference MNH/21612	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/GB 03/01627	International filing date *(day/month/year)* 15.04.2003	Priority date *(day/month/year)* 18.04.2002
International Patent Classification (IPC) or both national classification and IPC H03H9/02		
Applicant TRANSENSE TECHNOLOGIES PLC et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
29.10.2003	26.10.2004
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Plathner, B-D Telephone No. +49 89 2399-7987

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1-9 as originally filed

Claims, Numbers

1-18 received on 06.10.2004 with letter of 04.10.2004

Drawings, Sheets

1/2-2/2 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☒ the claims, Nos.: 19, 20
   - ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-18
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-18
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-18
	No:	Claims	

2. Citations and explanations

   see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1: WO0146684

D2: GB2355801

1 The subject-matter of method **claim 1** and its corresponding apparatus **claim 8** differs from the method of tracking a resonant frequency of a resonant structure known from D1 in that summing the reference signal with a second reference signal in order to excite two resonant structures is claimed.

Document D2 shows a method of monitoring the frequencies of two surface acoustic wave resonators via a single coupling means by summing the reference signals of two oscillators.

However, it cannot be fairly argued that a skilled person would arrive at the solution claimed in claim 2 by combining the teaching of D2 with the tracking method known from D1 because, in contrast to D1, the method of D2 is based on pulse excitation signals.

The concept of pulse interrogation significantly differs from variable frequency tracking concepts. The skilled person concerned with the problem of adapting a variable frequency tracking method in a way that two resonant structures can be tracked would therefore not think of analysing the teaching of documents related to the pulse interrogation concept.

The solution to the problem of tracking the frequency of two resonators by summing reference signals, as proposed in claim 1 and claim 8 of the present application, is therefore considered as involving an inventive step (Article 33(3) PCT).

4 Claims 2-6, 9-18 are dependent on claim 1 and claim 8 respectively and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Claims

1. A method of tracking the resonant frequency of an electrically resonant structure comprising the steps of exciting the resonant structure with a reference signal of a variable frequency encompassing the possible resonant frequency of the resonant structure, mixing a response signal from the resonant structure with the reference signal, filtering the mixed response and reference signals to remove the sum products from the composite signal, and using the resulting amplitude modulation component of the response signal within a control loop to track the resonant frequency of the resonant structure;
characterised by the further step of summing the reference signal from said oscillator with a second reference signal of a variable frequency encompassing the possible resonant frequency of a second resonant structure, the first and second resonant structures having a nominal difference frequency, exciting said first and second resonant structures with said mixed signal, mixing the composite response signal of said first and second resonant structures with the first reference signal, filtering the mixed signal and using the resulting signal within a control loop to track the resonant frequency of the first resonant structure, and mixing the composite response signal of said first and second structures with said second reference signal, filtering the mixed signal and using the resulting signal within a control loop to track the resonant frequency of the second resonant structure.

2. A method according to claim 1, wherein the or each mixed response and reference signals are filtered using a low pass filter.

3. A method according to claim 1 or claim 2, comprising the further step of suppressing the amplitude modulation of the or each reference signal by using a signal source of low output impedance.

4. A method according to any of the preceding claims, wherein the or each reference signal passes through an impedance before exciting the or each resonant structure.

5.. A method according to any of the preceding claims, comprising the further step, for the or each reference signal, of mixing the response signal with a phase shifted version of the or each reference signal, filtering said mixed signal, squaring the filtered in-phase and phase shifted mixed response and reference signals, summing the associated squared signals and using the result within a control loop to provide a phase compensated track of the resonant frequency of the associated resonant structure.

6. A method according to claim 6, wherein the reference signal is phase shifted through 90 degrees.

7. An apparatus for tracking the resonant frequency of an electrically resonant structure, comprising a variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency of said resonant structure, coupling means connecting said variable frequency oscillator to said resonant structure, an I-mixer forming a synchronous detector having a first input connected to said oscillator and a second input connected to the coupling device, the I-mixer mixing the excitation signal from the variable frequency oscillator with a response signal generated by the resonant structure in response to the excitation signal, a filter connected to the output of the I-mixer which filters the output of the I-mixer to remove the sum products of excitation and response signals, thereby leaving just an amplitude modulation component of the signal, and processing means which processes the filtered signal to track the resonant frequency of the resonant structure;

characterised in that a second variable frequency oscillator is connected to the coupling means, said first variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency of the first resonant structure and said second variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency of the second resonant structure, a second I-mixer forming a synchronous detector associated with the second oscillator having its first input connected to the second oscillator and its second input connected to the coupling device so as to mix the excitation signal from the second oscillator with a composite response signal received from said first and second resonant structures, and a second filter connected to the output of the second I-mixer which filters the output signal.

8. An apparatus according to claim 7, wherein said first and second resonant structure are connected in parallel.

9. An apparatus according to claim 7 or claim 8, further including a summer having first and second inputs connected to the first and second oscillators respectively, and an output connected to the coupling means.

10. An apparatus according to any of claims 7 to 9, wherein the or each filter is a low pass filter.

11. An apparatus according to any of claims 7 to 10, further comprising an impedance connected between the or each oscillator and the coupling device, the first input of the or each I-mixer being connected between its associated oscillator and its impedance and the second input of the or each I-mixer being connected between the associated impedance and the coupling device.

12. An apparatus according to any of claims 7 to 11, further including a Q-mixer associated with the or each oscillator having a first input connected to its associated oscillator by means of phase shifting means and a second input connected to the coupling means such that the or each Q-mixer mixes a phase shifted version of the excitation signal from its associated oscillator with the response signal, a filter connected to the output of the or each Q-mixer which removes the sum products of the phase shifted excitation and response signals, so as to leave just an amplitude modulation component of the signal, and further including means associated with the or each oscillator for squaring and then summing the filtered signals from the I- and Q-mixers associated with the or each oscillator, said processing means processing the sum of the squares of the filtered signals from said I- and Q- mixers, whereby phase delay effects are eliminated.

13. An apparatus according to claim 12, wherein the or each phase shifting means phase shifts the signal by 90 degrees.

14. An apparatus according to claim 12 or claim 13, wherein said means for squaring and summing said signals comprises first analogue signal squaring means connected to the filtered output of the or each I-mixer, a second analogue squaring means connected to the filtered output of the or each Q-mixer, and a summer associated with the or each pair of I and Q mixer having a first and second inputs connected to the outputs of the associated first and second squaring means.

15. An apparatus according to claim 14, wherein the said analogue signal squaring means each comprise a mixer having first and second inputs connected together to the output of its associated filter.

16. An apparatus according to claim 12 or claim 13, wherein said means for squaring and summing the signals comprises a digital processor, the output of each

filter being connected to an analogue to digital converter which is, in turn, connected to an input of the digital processor.

17. An apparatus according to claim 16, wherein the or each digital processor also calculates first harmonic amplitudes of the demodulated signals and produces codes for controlling the carrier frequency of the signal source.

18. An apparatus according to any of claims 7 to 17, wherein the coupling means is a rotational contactless coupler.